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(54) **Microphone systems of reduced in situ acceleration sensitivity**

(57) An electroacoustic assembly comprising a microphone having a diaphragm and supported on a face plate susceptible to vibratory effects. Vibration sensitivity is reduced by opposing the pressure effects on the diaphragm caused, on the one hand, by vibration of the assembly in the ambient air mass and by vibration of the air mass leading from the ambient air mass to the diaphragm, and on the other hand, by vibration of the effective mass of the diaphragm, generally augmented with additional mass, and including the effect of the internal air mass adjacent the diaphragm. Applications include hearing aids in which the microphone and its support are mechanically coupled to receiver components that may impart significant motion thereto.

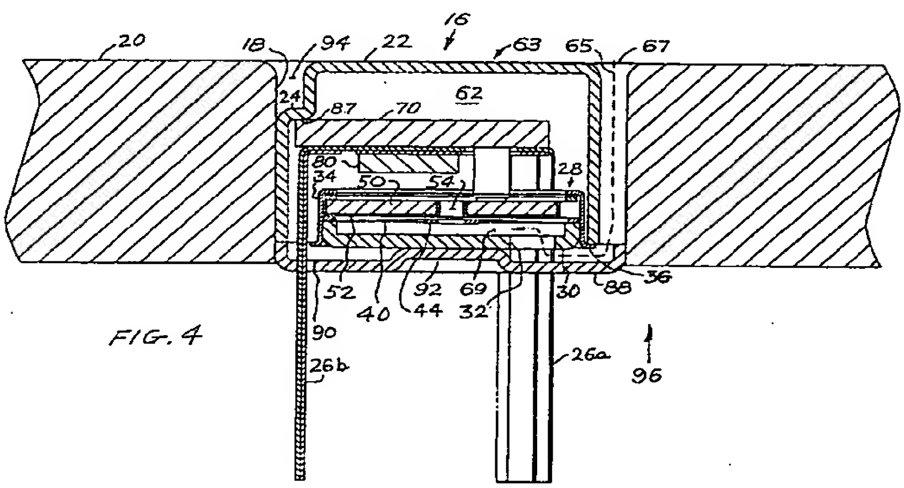

FIG. 4

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Description

Brief Summary of the Invention

This invention relates generally to microphone systems. More particularly, it relates to improved microphone assemblies having applications to in-the-ear (ITE) hearing aids. Such hearing aids include canal aids, which are worn by insertion mostly in the external auditory meatus of the wearer, and completely-in-the-canal (CIC) aids, characterized usually by an outer face mounted inwardly of the outer terminus of the auditory meatus.

In hearing aid systems the effective acceleration sensitivity of the microphone component is of major concern because of the potential for so-called mechanical oscillation in these tightly packed, low mass systems having substantial electronic gain in the loop comprising the microphone and the receiver (the electroacoustic output transducer). Typically, the receiver is a magnetic moving armature transducer having appreciable effective mass in its armature. In operation, the vibrating armature has both vibratory linear momentum and angular momentum. These momenta may be approximately canceled by corresponding momenta of another armature in a receiver system of siamese twin configuration, as described in the patent to Victoreen, U.S. patent 4,109,116. If these momenta are not canceled the entire receiver tends to vibrate, and to vibrate the microphone by mechanical coupling through the body or shell of the hearing aid. This may result in undesirable oscillation of the system.

Typically, the mounting of a receiver in a hearing aid cushions it against mechanical shock damage and attenuates somewhat the communication of vibration from the receiver to the hearing aid body or shell. In general, however, in smaller contemporary hearing aids such as canal or CIC aids, the mounting is not fully effective in providing this attenuation. Consequently it is important, in order to prevent oscillation of the system, that the effective acceleration sensitivity of the microphone be as small as possible.

Reduced acceleration sensitivity is one of the prime reasons for the almost complete dominance of electret condenser microphones in present day hearing aids. Typically the diaphragm of such microphones is a stretched membrane of biaxially oriented polyester (such as polyethyleneterephthalate) film, of roughly 1.5 micron thickness or less, and having a volume density of about 1.39 gram/cm^3. This corresponds to a surface density of about 212 microgram/cm^2. In terms of strictly diaphragm mass acceleration sensitivity, this in turn corresponds to a low frequency equivalent SPL (sound pressure level relative to .00002 Pascal) of only 60 dB at one G of acceleration applied to the microphone.

However, as observed in a paper by Mead C. Killion entitled "Vibration Sensitivity Measurements on Subminiature Condenser Microphones," Journal of the Audio Engineering Society, volume 23, pages 123-127 (March 1975), there are contributions to the acceleration sensitivity due to acceleration of the air mass in front of the microphone which may be significant and may, in mounted microphone systems, exceed the diaphragm mass contribution.

In the prior art the acoustically linked acceleration sensitivity observed by Killion has been accepted as unavoidable, and attention has been directed only at minimizing the diaphragm surface density by using thinner films. In such prior art microphone systems, the low frequency diaphragm mass and acoustical contributions to acceleration sensitivity have been additive.

According to the present invention, the low frequency diaphragm mass and net acoustical contributions are caused to be subtractive rather than additive, with the result that over a substantial frequency range the net acceleration sensitivity of the microphone system is less than that of diaphragm mass effects alone or of acoustical effects alone.

Accordingly, the present invention comprises an assembly including a microphone and a faceplate or similar support to which the microphone is secured. The microphone has a transducer casing which partially encloses an internal space and a diaphragm attached to the transducer casing and substantially completing the enclosure of said space. The microphone also has means supported within the transducer casing and responsive to volume displacement of the diaphragm to generate an electrical signal. The faceplate has a surface with an acoustic inlet therein open to sound waves in a sound propagating medium. The microphone is secured to the faceplate in a position whereby said internal space is located on the side of the diaphragm toward the acoustic inlet. The assembly of the invention also includes a passage for said medium communicating between said acoustic inlet and the side of the diaphragm opposite to said internal space.

Description of the Drawings

Fig. 1 illustrates the idealized axially symmetrical radiation of sound from a portion of a sphere, providing the basis for a theoretical and quantitative analysis of radiation impedance and an approximation of the conditions for a hearing aid in use.

Fig. 2 is a plot of the reactive component of the radiation impedance corresponding to Fig. 1.

Fig. 3 is a plot of the resistive component of the radiation impedance corresponding to Fig. 1.

Fig. 4 is an elevation in section of a first embodiment of the invention having a microphone flush-mounted in a faceplate.

Fig. 4a is an enlarged detail of Fig. 4.

Fig. 5 is an isometric view of the microphone of Fig. 4.

Fig. 6 is a partially exploded isometric view of the microphone of Fig. 4.

Fig. 7 is a view in plan showing circuit elements of the embodiment of Fig. 4.

Fig. 8 is an isometric view of the backplate of Fig. 4.

Fig. 9 is an isometric view of the microphone of Fig. 4 without the cap 88.

Fig. 10 is an elevation partly in section of a second embodiment of the invention.

Fig. 11 is an elevation partly in section of a third embodiment of the invention.

Fig. 12 is an isometric view of an alternative form of microphone according to the invention.

Fig. 13 is an elevation in section of the microphone in the embodiment of Fig. 12.

Fig. 14 is a schematic view of a first form of CIC aid according to the invention.

Fig. 15 is a schematic view of a second form of CIC aid according to the invention.

Detailed Description

Fig. 1 illustrates the axially symmetric radiation of sound from a portion of a sphere, assumed for purposes of explanation to approximate one of the important acoustical contributions to the acceleration sensitivity of a microphone system in an ITE hearing aid. In the results shown below, Fig. 1 together with the lossless acoustic wave equation, has a solution that is a singly infinite expansion involving products of Legendre polynomials and spherical Bessel functions, and thus is fairly readily calculable. See Morse, Vibration and Sound, 323-326 (second edition 1948).

In Fig. 1, a rigid sphere 12 of diameter 2a = 15 centimeters represents the head of a hearing aid wearer. Absorption or radiation by the head, and scattering by the concha and pinna, and scattering by the neck, etc., are neglected. A circular piston 14, vibratory by translation along the axis of symmetry, and of diameter 2b = 1.2 centimeter, represents the outer face of a canal aid which extends out somewhat into the concha cavum but tucks under the tragus. In particular the radiation of sound by the piston 14 represents the outward radiation of sound by a vibrating canal aid. Such vibration may result, for example, from vibration of the armature of the receiver causing the body or shell of the aid to vibrate. Note that in this model, any vibration of the piston perpendicular to the axis of symmetry results in negligible radiation, and this applies also to an actual canal aid except insofar as such vibration excites vibration of the head or outer ear. It is also recognized that axial vibrations of an ITE aid can also be expected to couple somewhat to the head.

Subject to the foregoing remarks, an analysis of the approximate system of Fig. 1 has both qualitative and quantitative significance. In the following evaluation, the inlet port of or leading to the microphone is assumed to sample the radiation pressure at a concentrated point "p" located at the center of the outer surface of the piston. In addition, the microphone is assumed to be rigidly mounted to the piston 14, so that its casing(s) undergo substantially the same vibratory acceleration as the piston. Correspondingly, in actual hearing aids the microphones of this invention are intended to be mounted rigidly to a faceplate which provides the outer surface of an ITE aid.

Figs. 2 and 3 correspond to Fig. 1, and are linear-linear plots of the reactive and resistive components, respectively, of the specific acoustic radiation impedance. This impedance is defined as the ratio of the pressure at the center of the piston to its mechanical velocity, in each case divided by $\rho_o c$, wherein ρ_o is the density of air and c is the speed of sound, both at 37°C. The range of frequency f plotted is 100 to 10,000 Hertz. The broken straight line in Fig. 2 shows the initial slope of the specific acoustic radiation reactance Xs, and helps to show that the nearly frequency proportional reactance corresponds to a nearly constant inertial effect. In fact, this slope corresponds to a pressure to acceleration ratio of $.0740\rho_o a = 6.31(10^{-4})$ g/cm^2, i.e. 631 micrograms/cm^2, about three times that of the typical diaphragm surface density noted above. There are other air masses associated with a practical microphone that in general are additive to the radiation effect, with the result that the diaphragm mass effect is almost inconsequential in contemporary prior art electret condenser microphones.

The specific acoustic radiation resistance Rs shown in Fig. 3, although relatively small at most frequencies of interest, causes a phase shift in the radiation pressure and therefore has a bearing on the subtractive inertial effects that are achieved according to the present invention. The functions Xs and Rs are accurate for the configuration of Fig. 1, but are only indicative of the radiation impedance of an actual canal aid when in use. In addition, the functions Xs and Rs depend on the diameter chosen for the piston of Fig. 1.

A preferred embodiment of the invention, which provides a means to counteract the radiation impedance predicted by the foregoing approximate analysis, is shown in Figs. 4, 4a and 5 to 8. Fig. 4 is a diametral cross section of a microphone 16 mounted in a circular aperture 18 of a faceplate 20. Fig. 4a is a magnified portion of Fig. 4. Fig. 5 is an isometric view of the complete microphone. Fig. 6 is a view of the microphone 16 partially exploded along its axis. Fig. 7 is a plan view of the electronic circuitry incorporated in the microphone. Fig. 8 is an isometric view of the microphone's electret coated backplate.

In this embodiment the microphone 16 has a drawn metallic casing 22 having at least three integral ridges 24 which space and mount the microphone, while allowing sound passage roughly axially along the remaining cylindrical portions of its exterior.
The ridges 24 also allow passage of three flex leads 26a, 26b and 26c from the internal electronic circuitry of Fig. 7 to the exterior of the microphone and to electrical connections to other circuitry of a hearing aid or other electronic device.

An electret cartridge subassembly 28 has a drawn cup 30 blanked with acoustic apertures 32, and a retainer 34, drawn and blanked to form a central open-

ing, and having a flange 36 notched locally to avoid electrical shorting of the flex leads.

The cartridge 28 is shown in more detail in Fig. 4a. The cup 30 is coined to sharpen its inside radius, and also to provide a flat edge 38. Typically the cup 30 is gold plated. To the edge 38 is adhesive bonded under tension a polyester film diaphragm 40 which is so thin that it is shown simply as a line in Figs. 4 and 4a. The film from which diaphragm 40 is fabricated is thinly gold coated, as by vacuum evaporation, on the side which will face the cup 30. The gold coating renders the diaphragm 40 electrically conductive, and enables it to function as the movable electrode in a capacitive transducer comprising the diaphragm 40 and an electret coated backplate 42. An added mass 44 is bonded to the diaphragm for reasons discussed below. A shim washer 46, typically photoetched from metallic foil, spaces the diaphragm at its peripheral edge from the electret coated backplate at tabs 48 on the latter, shown in Fig. 8. The substrate 50 of the backplate 42 is metallic, typically gold plated to provide reliable electrical contact. An electret coating 52 on the backplate is typically a discrete film of a fluorocarbon polymer, usually a copolymer of tetrafluoroethylene and hexafluoropropylene, which is melt coated onto one major face and the edges of the backplate's substrate. Although most of the backplate 42 is spaced radially inward from the shim 46 to allow acoustic passage between the diaphragm 40 and the major interior spaces of the microphone, and also to reduce the electrical leakage capacitance between the backplate and the surrounding structure of the cartridge 28, a central aperture 54 is provided in the backplate for additional acoustic passage and reduces the acoustic damping between the diaphragm 40 and the outer face of the electret coating 52. A very small aperture 56 (Fig. 4a) is controllably produced, as by eximer laser, in the diaphragm 40 to provide atmospheric pressure venting of the interior spaces of the microphone. It is desirable for practical reasons to locate the aperture 56 in line with the aperture 54, and in order to do this the mass 44 is preferably in the form of a ring or washer. In Figs. 4 and 4a, the thicknesses of the shim 46 and mass 44, and the degree of sag of the diaphragm 40 toward the electret coating 52 caused by electrostatic attraction, are exaggerated for the sake of clarity.

Prior to the making of the subassembly of the cartridge 28, the electret coating 52 may be negatively charged by a combination of the corona and thermal methods known in the art. The components of the cartridge 28 are completed by insulating washers 58 and 60 which space between the retainer 34 and the metallic surfaces of the tabs 48, and apply a moderate force to the tabs to ensure a stable subassembly of the electret cartridge 28.

This force is maintained by welds between the retainer 34 and the cup 30, as by small laser welds through the wall of the retainer into the wall of the cup. In addition, adhesive is applied to the seam between the cup 30 and retainer 34 to acoustically seal between them. The washer 58 may be blanked from low dielectric constant film such as dispersion cast polytetrafluoroethylene. The washer 60 may be the same material as the electret coating 52, and may for convenience melt bond the washer 58 to the retainer 34. Preferably, however, the washers 58 and 60 are fabricated in one step from prelaminated or precoated film.

As above described, and upon completion of the assembly as described below, the casing 22 and parts of the cartridge 28 partially define and enclose an interconnected internal space 62 on one side of the diaphragm 40, and as such they are referred to collectively herein as the "transducer casing" 63. The diaphragm 40 substantially completes the enclosure of the space 62 except for the very small aperture 56. The spaces between the external surfaces of the casing 22 and the internal surface of the aperture 18 in the faceplate form an air passage shown by a broken line 65 leading from an acoustic inlet 67 formed at the surface of the faceplate to a chamber 69 on the side of the diaphragm opposite to the internal space 62.

A second subassembly is made before insertion in the casing 22, and comprises a circuit and lead subassembly partially detailed in Fig. 7. A laminated circuit 64, including the leads 26a, 26b and 26c, is photoetched in the flat from a suitable laminate such as copper foil/polyimide film. Preferably the exposed surface of the copper is gold plated, with an intermediate plating substantially suppressing the diffusion of copper into the gold plating. As part of the process of fabricating the laminated circuit 64 while flat, a U-shaped slot, partially shown at 66, is blanked in the polyimide film. This allows a connector 68 to be formed up and over in an operation that also forms up the leads 26a, 26b and 26c. The formed laminated circuit 64 is adhesive bonded to a mechanically stiff electrically insulating substrate 70 (Fig. 6). The substrate 70 may itself comprise a circuit board, and may be formed of a high alumina ceramic, for example.

With reference to the plan view of Fig. 7 the lead 26c is a ground lead and extends to a pad 72. The lead 26b is a power supply lead and extends to a pad 74. The lead 26a is an output lead and extends to a pad 76. The connector 68 extends to a pad 78. The metallic foil underlying a semiconductor amplifier die 80 extends to a pad 82. The die 80 is mechanically mounted and electrically connected at its underneath surface by silver pigmented die attach epoxy.

The pads 72, 74, 76 and 78 are connected by bond wires 84 to corresponding pads 86 as supplied on the die 80. Each of the bond wires 84 loops up away from the pair of wire bonds at its ends, especially to clear the bond wires 84 from the remaining surface of the die 80. In particular, the bond wire loop from pad 72 to its corresponding die pad 86 also clears the output conductor from lead 26a to pad 76, to avoid shorting the output conductor to ground.

The die 80 preferably comprises a preamplifier and

may be of the type disclosed in the copending application of Madaffari and Collins, Serial No. 08/447,349 filed May 23, 1995. In the structures of Madaffari and Collins, a shunt connected discrete capacitor typically rolls off high frequency noise, and the capacitor may be physically larger than the die 80. Although not shown in Fig. 7, such capacitor may be located on the side of the substrate 70 opposite to the die 80, and may be electrically connected to the amplifier die 80 by a wire bond to pad 82.

After appropriate cleaning operations, the die 80 and all of its bond wires 84, including the wire bonds, are encapsulated in a semiconductor grade blob top (not shown), the latter being pigmented black to render it substantially light opaque. High temperature oven cure of the blob top encapsulant completes the circuit and lead subassembly.

By means of the leads 26a, 26b and 26c, the amplifier circuit of the die 80 is connected to additional circuits (not shown) comprising the hearing aid receiver. Typically, the receiver includes a magnetic moving armature transducer for converting from electrical to acoustic energy, and is partially contained by an aid enclosure of which the faceplate 20 is a part.

With particular reference to Figs. 4 and 6, the circuit and lead subassembly may now be adhesive bonded into the casing 22. Truncated corners of the substrate 70 rest on terminal flats such as 87 of the ridges 24. The leads 26a and 26b are electrically insulated from the ridges 24 by the extra width of their insulating film, but the ground lead 26c has full width of its foil to help enable the required reliable electrical contact of the ground lead to the casing 22. This may be accomplished by silver epoxy to the interior of the corresponding ridge 24 near the pad 72, provided that the casing 22 has a noble metal surface such as gold plating.

Next, the electret cartridge 28 may be adhesive bonded into place in the casing 22, the adhesive peripherally sealing except where the ridges 24 are located, and with the flange 36 locating the cartridge against the edge of the casing. The notches in the flange 36 are aligned with the leads 26a, 26b and 26c. Preferably the flange 36 is welded to the edge of the casing 22 in at least one location to establish definite electrical contact. The connector 68 springs against the backplate 42 to provide electrical contact, and if desired this may be augmented with silver epoxy. Sufficient adhesive is applied between the interior of the ridges 24 and the adjacent wall of the retainer 34, near the outer edges of the ridges 24, and on both sides of the leads 26a, 26b and 26c, to ensure an acoustic seal at each of these regions.

The assembly of the microphone described above is completed by addition of a slotted cap 88 which, with its slots 90 threaded by the leads 26a, 26b and 26c, is edgewise butted against the opposing edges of the ridges 24.

The outside diameter of the cap 88 is nominally the same as the diameter of the casing 22 overall including its ridges 24. Preferably the cap 88 is strongly attached to the casing 22 by small laser welds which overlap the seams between the cap and the ridges 24. The cap 88 also has a formed boss 92 which is adhesive bonded to the cup 30. The assembly is completed by adhesive which strongly bonds and seals in the slots 90 all around the flex leads 26a, 26b and 26c where threaded.

Fig. 4 shows the microphone 16 bonded and sealed into the hearing aid faceplate 20 within its circular aperture 18. Preferably the outer face of the casing 22 is substantially flush with the outer surface of the faceplate. Beginning with an annulus 94, passages such as 65 transmit vibratory acoustic flow to and from the front chamber 69 between the diaphragm 40 and the cup 30 The flow passages are fairly long, but their relatively large area keeps within reason the acoustic inlet impedance to the chamber 69. Thus when the microphone 16 is not vibrating as a whole, it functions in an essentially conventional manner.

When the microphone 16 is functioning in a hearing aid, it is vibrating with the faceplate 20, primarily in response to vibration of the hearing aid induced by the receiver, as discussed above. In general, a substantial component of the vibration will be along the axis of the microphone, and it is this component that causes most of the radiation pressure associated with the vibrating outer surfaces of the faceplate 20 and microphone casing 22 in combination. Thus the microphone senses two superposed pressure signals: (1) the pressure associated with waves emanating from external sources, as affected by passive scattering by the head, etc., and (2) the radiation pressure associated with hearing aid (and head) vibration, as augmented by the air masses forming the passage 65. It is the pressure (2) that is of primary concern, since it creates the potential for feedback oscillation.

The operation of the invention can be explained to an approximation by considering the operation at a low frequency in which the air masses of the passage 65, the air mass in the interior space 62 of the microphone, the mass 44, and the self-mass of diaphragm 40, all move substantially although not exactly with the microphone 16 as it vibrates. For an approximation, the radiation resistance such as Rs (Fig. 3) is neglected. On these assumptions, as the microphone 16 is accelerated in a direction 96 (Fig. 4), the radiation reactance such as Xs (Fig. 2), augmented substantially by the air masses in the passage 65, produces a positive signal pressure in the chamber 69 and an upward force in the direction 96 on the diaphragm 40. However, the acceleration in the direction 96 of the self-mass of the diaphragm 40, the mass 44, and the effective air mass in the space 62, produces a downward reaction force in and on the diaphragm 40 in the direction opposite to the direction 96.

Since the substantially frequency proportional radiation reactance such as Xs corresponds to a substantially constant mass-like effect, significant cancellation of the upward and downward forces on the diaphragm 40

results, thus achieving the primary object of the present invention.

The following considerations are also pertinent to the foregoing low frequency approximation. The acoustic impedance of the vent aperture 56 in the diaphragm 40 is essentially resistive and frequency independent, and is required to be high enough to be acoustically insignificant at frequencies of interest from the point of view of cancellation of acceleration signals. Because of approximate volume conservation in the space 62, about half of the mass of air in this space is effective in producing reaction pressure on the diaphragm. Consequently the air mass effect in the passage 65 considerably outweighs that of the space 62. The added mass 44 is required to bring the cancellation effect roughly into balance, and also to individualize sufficiently the choices of microphones available. The slope of the radiation reactance such as Xs depends on the hearing aid face size, and also on its location in the ear, thus requiring a choice of differing masses 44. The choice of a small additional ring or washer for the mass 44 is dictated by the practical need to have a constant film thickness and elastic tension stress for the diaphragm 40. Ideally, the added mass may be distributed uniformly over the diaphragm without altering its other characteristics.

A simplified equivalent circuit model of the accelerated microphone, in which the mass 44, the self-mass of the diaphragm 40, and the effective air mass of space 62 are lumped into a single mass, indicates that complete cancellation of the acceleration signals cannot be achieved even in principle over a finite frequency range. The radiation reactance such as Xs departs from a constant slope, the radiation resistance such as Rs becomes non-negligible, and the impedance and coupling of the air masses in the passage 65 are changed by viscosity and other effects. In addition, the inductance representing approximately the radiation reactance plus the passage 65 mass effects is shunted by a capacitance representing the chamber 69 plus some of the passage 65 compressibility effects, while the lumped mass associated with the diaphragm 40 is not so shunted. However, if the resonant frequency of this inductance-capacitance pair is placed well above the required passband of the microphone, and if the Rs/Xs ratio of the radiation impedance is fairly small over that passband, a substantial degree of cancellation of the acceleration signals can be achieved over the entire passband of the microphone, and generally this is sufficient for practical applications. Although the specific acoustic radiation impedance usually is not choosable, the highest inductance-capacitance resonant frequency usually will be obtained by designing the cross sectional areas in the passage 65 as large as practical.

Fig. 9 shows a microphone 98 comprising a variation of the microphone of Figs. 4 to 7, this variation differing only in that the cap 88 is omitted. As shown in Fig. 10, the microphone 98 is adapted for mounting from the outside of a faceplate 100 in a semi-blind circular recess 102 molded in the faceplate 100, with the flex leads 104 threaded through slots 106 sealed acoustically tight by the hearing aid manufacturer around each lead. A molded boss 108 spaces the cup of the microphone 98 from the remainder of the bottom of the recess, to provide acoustic access to the apertures in the cup. This variation and its mounting avoids the tendency toward constriction of the passage 65 in the microphone (Fig. 4), between the rim of the cap 88 and the inwardly spaced portions of the rim of the casing 22.

A further variation is shown in Fig. 11, in which the microphone 98 described with reference to Fig. 10 is welded into a circular outer casing 110 which provides appropriate slots and a locating boss 112. In this embodiment the microphone 98 has its leads 113 strongly and tightly bonded into each of slots 114. This variation is for applications which require mounting on the inside of a faceplate 116. The edge of the outer casing 110 extends beyond the outside bottom of the casing 22, and this edge mounts and seals into a shallow circular recess 118 in the faceplate. An aperture 120 in the faceplate 116 provides acoustic inlet to the internal microphone 98, but also results in considerably longer acoustic passages than the passage 65 of the microphone 16 as shown in Figs. 4 to 7.

An alternative embodiment of the microphones of the present invention is shown at 122 in Figs. 12 and 13. This embodiment is intended to be mounted as in Fig. 11, but with the recess in the faceplate fitting the cross sectional shape of an outer casing 124. Fig. 13 is a section of the microphone 122 as cut by a plane containing the central axis of the microphone and a diagonal passing through points 126-126 shown in Fig. 12.

The outer casing 124 is provided with a slot 128, recessed on one side as shown at 130, to receive by axial translation a circuit and terminal board 132. The board 132, typically of a high alumina ceramic, has a multiplicity of terminal pads at 134 for solder connections, and surface conductors on the board running from the terminal pads into the interior of the microphone under the recess 130, which prevents shorting of the conductors. The microphone 122 also has an inner casing 136 which, when assembled, is welded into the outer casing 124. The inner casing 136 has four acoustic apertures 138, and is pinch coined at 140 to receive and locate a cap 142. The inner casing 136 is slotted with the same pattern as the recessed slot 128, 130 on the side adjacent thereto. On the opposite end of its diameter the casing 136 is slotted as at 144 with the pattern of the slot 128 but without the recess 130. Prior to placement of the cap 142, the board 132 and the semiconductor and other circuitry (not shown) mounted on it, may be slid axially into the slots, the slots in both casings locating and supporting the board.

The inside radius of the inner casing 136 is sharpened in a secondary operation to receive a diaphragm tensioning and support ring 146. To this is adhesive bonded under tension a gold coated diaphragm 148, which carries an additional ring mass or washer 150,

and also has an atmospheric pressure vent aperture 152. The diaphragm subassembly is bonded into the inner casing 136 with silver epoxy at the metallic ring 146. A shim washer 154 spaces between the rim of the diaphragm 148 and the tabs of an electret film coated backplate 156 of the form shown in Fig. 8. The backplate 156 is fixed to the inner casing 136 by insulating epoxy paste adhesive fillets (not shown) onto the metallic surfaces of the backplate's three tabs.

Electrical contact to an input conductor at an edge of the board 132 is made by a silver epoxy fillet to the exposed metallic surface of the backplate. Likewise, the ground contact between the appropriate conductor on the board 132 and the inner casing 136 is made by a silver epoxy fillet. Typically the inner casing 136 and the metallic portion of the backplate 156 are gold plated for this purpose, and typically the conductors on the board 132 are noble metal frit bonded coatings fired at high temperature.

The cap 142 has the filler key 158 welded onto it. When the assembly of the microphone 122 is completed by adhesive bonding of the cap 142 in place against the step of the pinch coin 140, the key 158 substantially fills the remainder of the slot left by the board 132. Sufficient adhesive must be used to block all potential leaks, except the vent aperture, between all of the corner spaces 160 and the exterior of the microphone 122 or the interior space 161. In particular, sufficient adhesive must be used to block the remainder of the slot 144 and the recesses 130 in both of the casings 124 and 136.

Figs. 14 and 15 illustrate schematically the application of the microphones of the present invention to CIC hearing aids. CIC hearing aids 162 and 164, respectively, are shown in position in the auditory meatus 166 of the user.

In Fig. 14 the outer face 168 of a faceplate of the CIC aid 162 is roughly flush with the outer terminus of the meatus 166. A microphone 170 is flush mounted in the faceplate as in Fig. 4 or Fig. 10, and is located more or less centrally on the outer face 168. Flex leads 172 of the microphone 170 are shown schematically as in Fig. 5 or Fig. 9, and the interior of the faceplate of CIC aid 162 is not indicated. The receiver elements 174 of the aid 162, the cause of its vibration, are located at or near the end 176 toward the tympanic membrane 178. The specific acoustic radiation impedance, as defined above, of the outer face 168 of the CIC aid 162 is typically less than that of a typical canal aid because of the smaller area of the face 168, even though there is additional air mass in the concha cavum 180. During vibration of the aid 162, the microphone 170 senses the resulting radiation pressure, in addition to its internal inertial effects, over the annular inlet, essentially at the effective center of the outer face 168.

When the added mass 44 (Fig. 4a) of the microphone 170 is appropriately chosen, say from a discrete set of choices for practical reasons, the total acceleration induced signal of the microphone 170 is much reduced compared with prior art microphones over a very substantial frequency range.

In Fig. 15 the CIC aid 164 is mounted with its outer face 182 inward of flush, and its inner end 184 is inserted more deeply toward the tympanic membrane 178. Generally the specific acoustic radiation impedance of the outer face 182 will be greater than that of the outer face 168 of Fig. 14, as a result of the further additional air mass in the auditory meatus 166 between the outer face 182 and the concha cavum 180.

When the user of an ITE hearing aid incorporating a microphone system of this invention attempts to use a telephone while the aid is in acoustic mode, the hearing aid is apt to go into oscillation, particularly if this microphone system is necessary to avoid oscillation in normal use. This is because the complex radiation impedance such as Rs + iXs is considerably affected by the proximity of the telephone's receiver. Consequently a telecoil mode is needed in hearing aids of this type. Such hearing aids will tend to be cosmetically acceptable, and often quite inaccessible when worn, so switching between acoustic mode and telecoil mode will be most convenient if done by remote or accomplished automatically.

In the foregoing description references are made to specific applications of the invention to hearing aids. However, it is not inherently limited to such applications. For example, references are made to a "faceplate." In microphone applications other than hearing aids the faceplate described herein may be replaced by a frame, outer casing, support or other structure housing or retaining a microphone and structured according to the teachings of this invention as herein described and claimed. Accordingly, the term "faceplate" is intended to include generically any such alternative or replacing means as well as hearing aid faceplates.

Likewise, although the invention has been described in relation to an air environment, other applications may involve its use in other acoustic transmitting media comprising the environment, such as other gases or liquids including water, for example.

Claims

1. Electroacoustic means including a structure (20, 22, 100, 116, 110, 124, 162, 164) having a vibratile surface (168, 182) and adapted to support said surface in a position exposed to external acoustic signals, and a microphone (16, 98, 122, 170) having a compliant diaphragm (40, 148) supported therein and means (28) responsive to vibrations of the diaphragm to produce electrical signals, said vibratile surface and a surface of the diaphragm facing in generally opposite directions, the microphone being mechanically coupled to said structure, characterized by means (20, 22, 88, 98, 100, 110, 116, 124, 136) forming a passage (65, 120, 160) for said external acoustic signals to said surface of the diaphragm.

2. Means according to claim 1, in which said vibratile surface comprises an external surface of the microphone.

3. Means according to claim 1 in which said structure is adapted for insertion in the ear, and including means comprising an electroacoustic receiver (174) adapted to convert said electrical signals to amplified acoustic signals transmitted to the tympanic membrane (178) of the ear.

4. Means according to claim 3, in which the receiver is mechanically coupled to said structure.

5. Means according to claim 1, in which said structure defines an aperture (18, 67, 94, 102, 120) open to said external acoustic signals and communicating with said passage.

6. Means according to claim 2, in which said structure and said microphone define an aperture (18, 67, 94, 102) open to said external acoustic signals and communicating with said passage.

7. Means according to claim 1, in which said passage is open in said external acoustic signals near said vibratile surface.

8. Means according to claim 1, in which said surface of the diaphragm substantially closes a space (69) communicating with said passage.

9. Means according to claim 1, in which the microphone includes an electret coated backplate (42, 156), the diaphragm and backplate forming an electret condenser transducer (28).

10. Means according to claim 1, in which the diaphragm comprises a film and a mass (44, 150) on the film to increase its reactance to vibration.

11. Means according to claim 1, in which the microphone has a casing (22, 30, 88, 136, 142) partially enclosing a internal space (62, 161), the diaphragm being attached at its periphery to the casing and substantially completing the enclosure of said space, said surface of the diaphragm being external to said space.

12. Means according to claim 11, in which said responsive means (28) is located within said internal space (62, 161).

13. A microphone according to claim 11, in which the casing encloses a space (69) on the side of the diaphragm opposite to said internal space (62, 161) and communicating with said passage (65, 120, 160).

14. Means according to claim 11, in which said structure comprises a faceplate (20, 100, 116) having an acoustic inlet (67, 102, 120) in said vibratrile surface and communicating with said passage (65, 120, 160) , the microphone being secured to the faceplate with said internal space (62, 161) located on the side of the diaphragm toward said inlet.

15. Means according to claim 14, in which the faceplate has an aperture (18, 102, 120) and the casing is received in said aperture, said passage including spaces formed between the casing and the aperture.

16. Means according to claim 15, in which the casing includes wall portions (24) forming ridges fitted to said aperture.

17. Means according to claim 16, in which said responsive means includes a plurality of electrical leads (26a, 26b, 26c, 104, 113) each extending within a ridge to the exterior of the casing, the diaphragm extending internally of said leads.

18. Means according to claim 11, in which the casing includes a plurality of wall portions (24) forming substantially parallel ridges, and electrical leads (26a, 26b, 26c, 104, 113) each extending within each of said ridges from said internal space (62, 161) to the exterior of the casing, the diaphragm extending internally of said leads.

19. Means according to claim 15, in which an external wall of the casing (22) is substantially flush with said vibratile surface near said acoustic inlet (67, 102).

20. Means according to claim 14, including receiver means (174) responsive to said signals to produce an acoustic output, and means (162, 164) connecting with the faceplate and partially enclosing and mechanically coupling the microphone and receiver.

21. Means according to claim 14, including an outer casing (110, 124) secured to the faceplate, the casing (22, 136) partially enclosing said internal space (62, 161) being secured within the outer casing, the outer casing having an opening to said passage.

22. Means according to claim 11, in which said internal space has a static pressure vent (56, 152) having an acoustic impedance sufficient to substantially eliminate its effect upon acceleration forces active on the diaphragm and caused by vibration of the microphone.

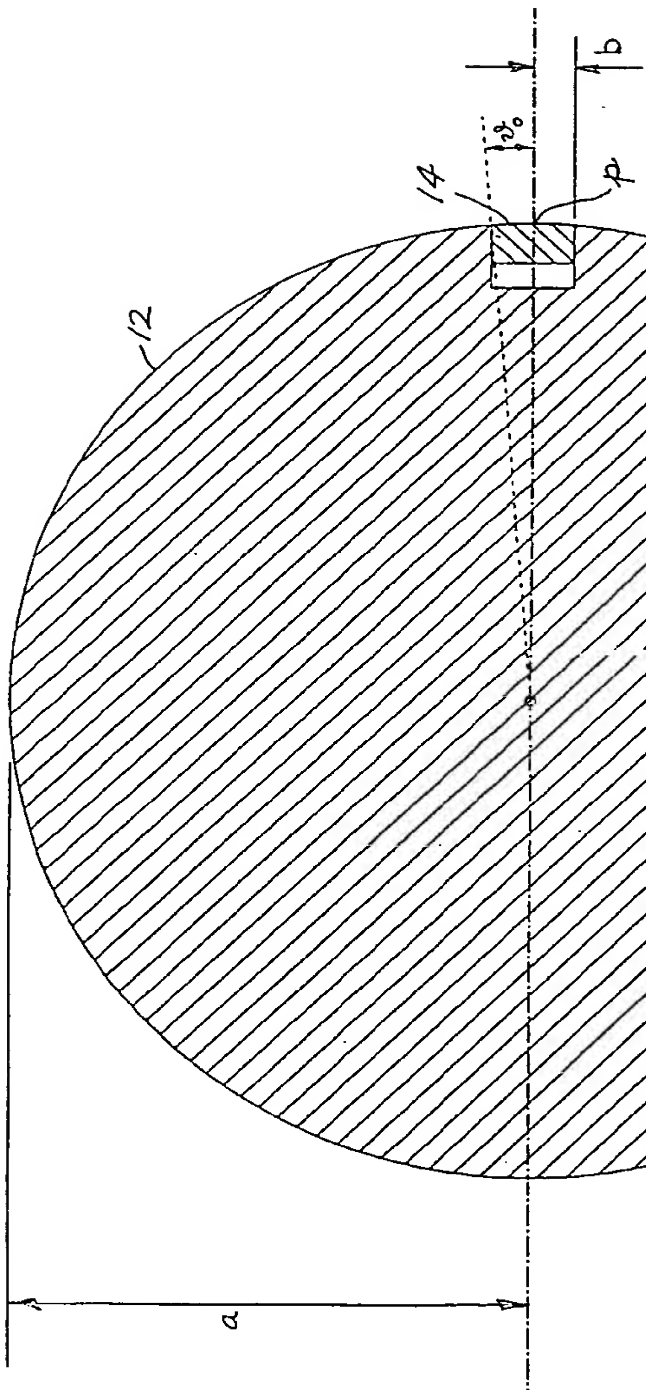
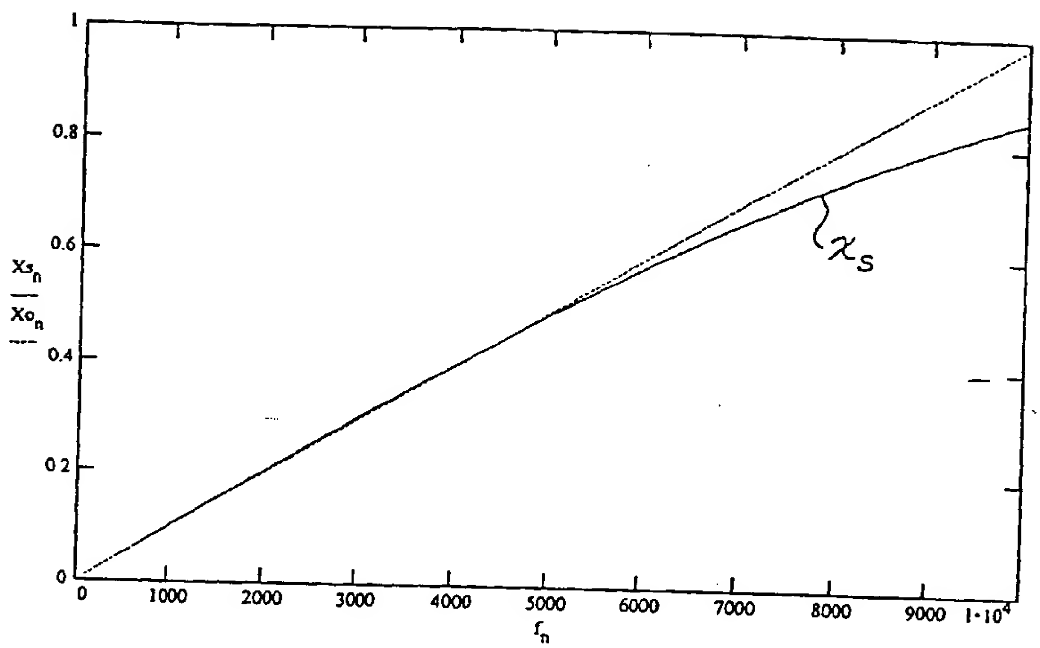


FIG. 1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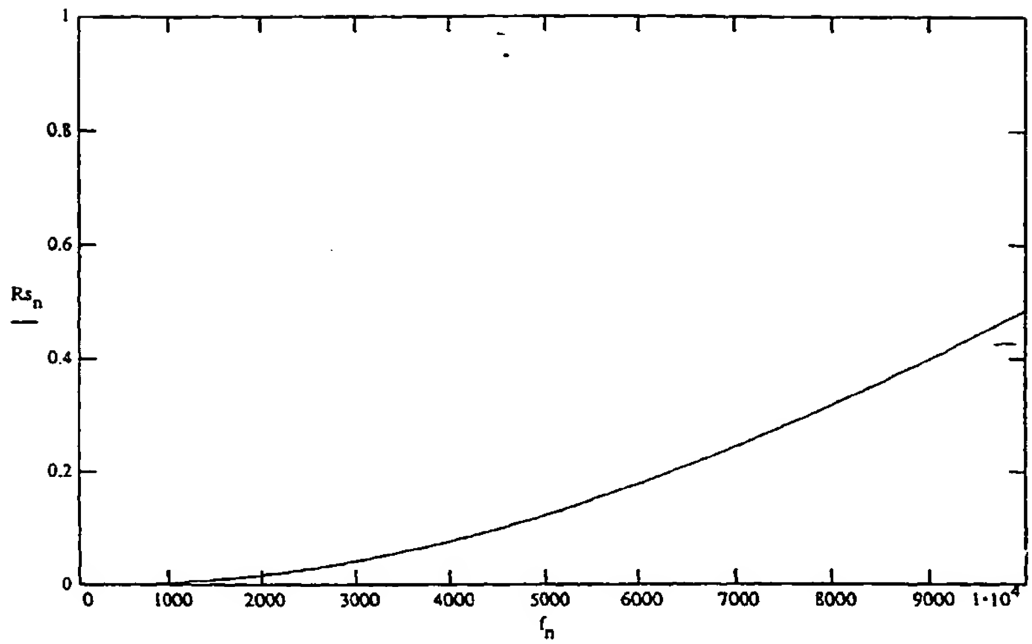
0.6
0.4
0.2
0
$\frac{Xs_n}{Xo_n}$
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
$1\cdot10^4$
f_n
χ_S

FIG. 2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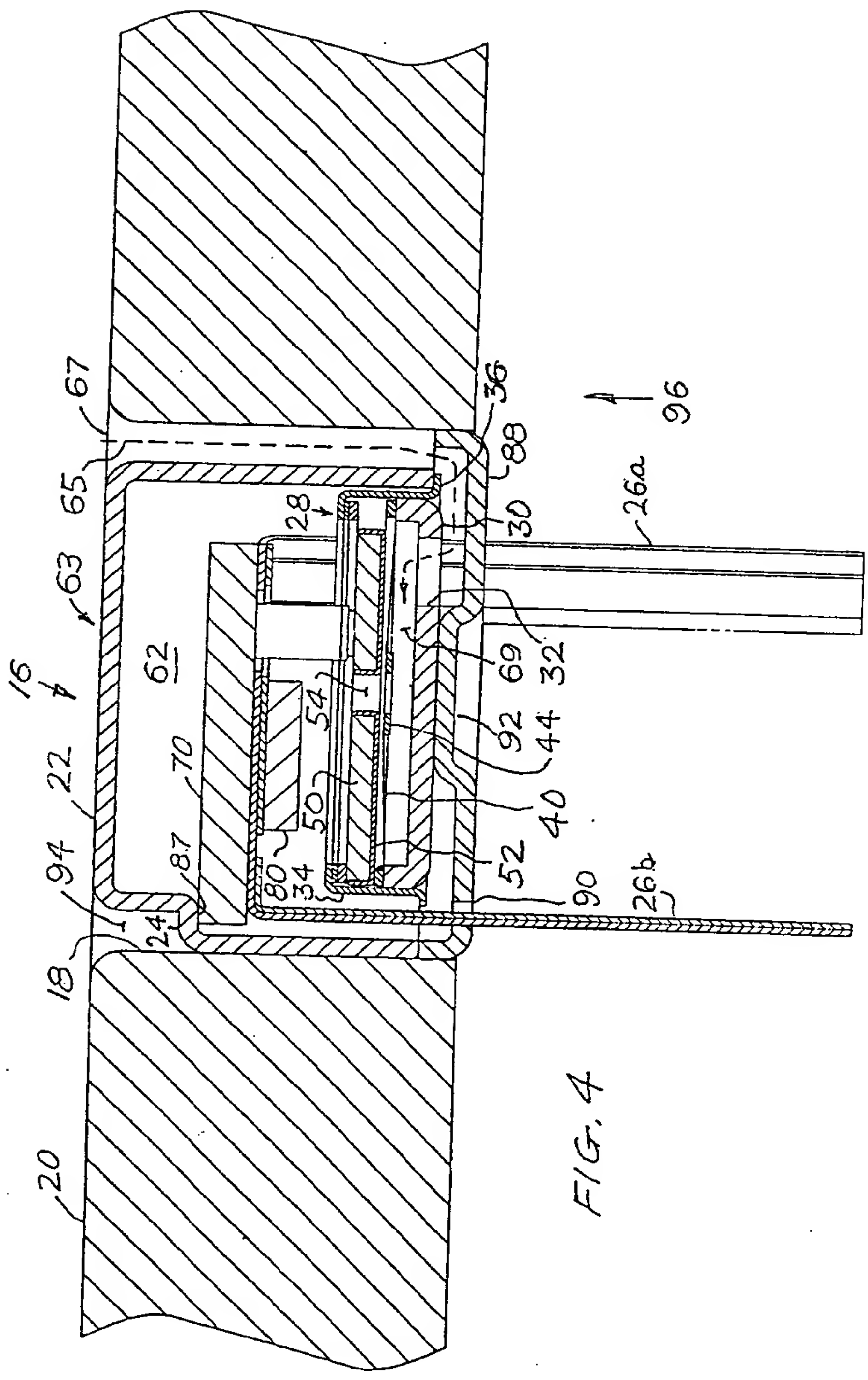
$1 \cdot 10^4$
f_n

FIG. 3


67
36
96
88
65
28
30
26a
63
62
16
69
32
54
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44
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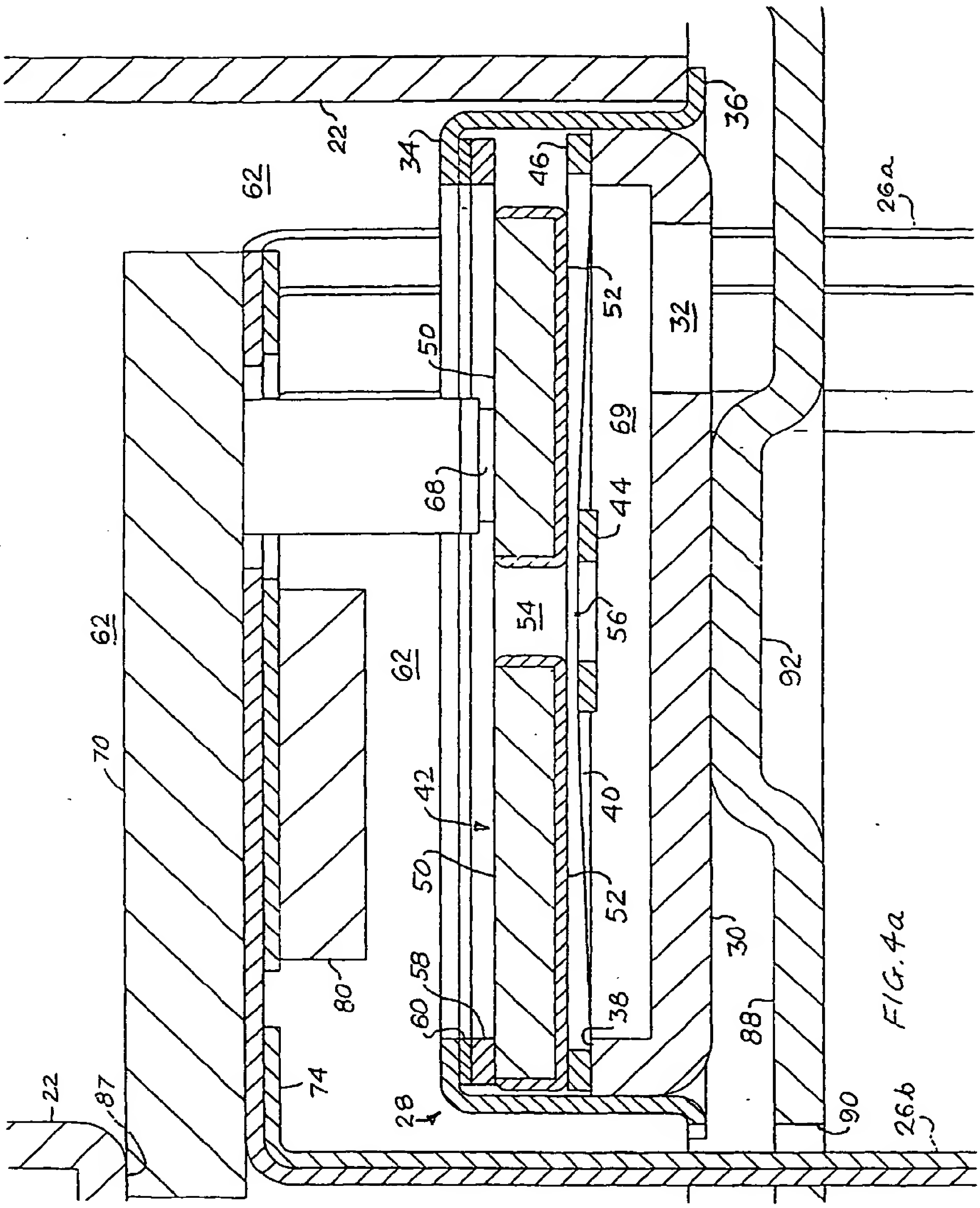
70
50
40
94
87
80
34
52
90
26b
24
18
20

FIG. 4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74
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90
26b

FIG. 4a

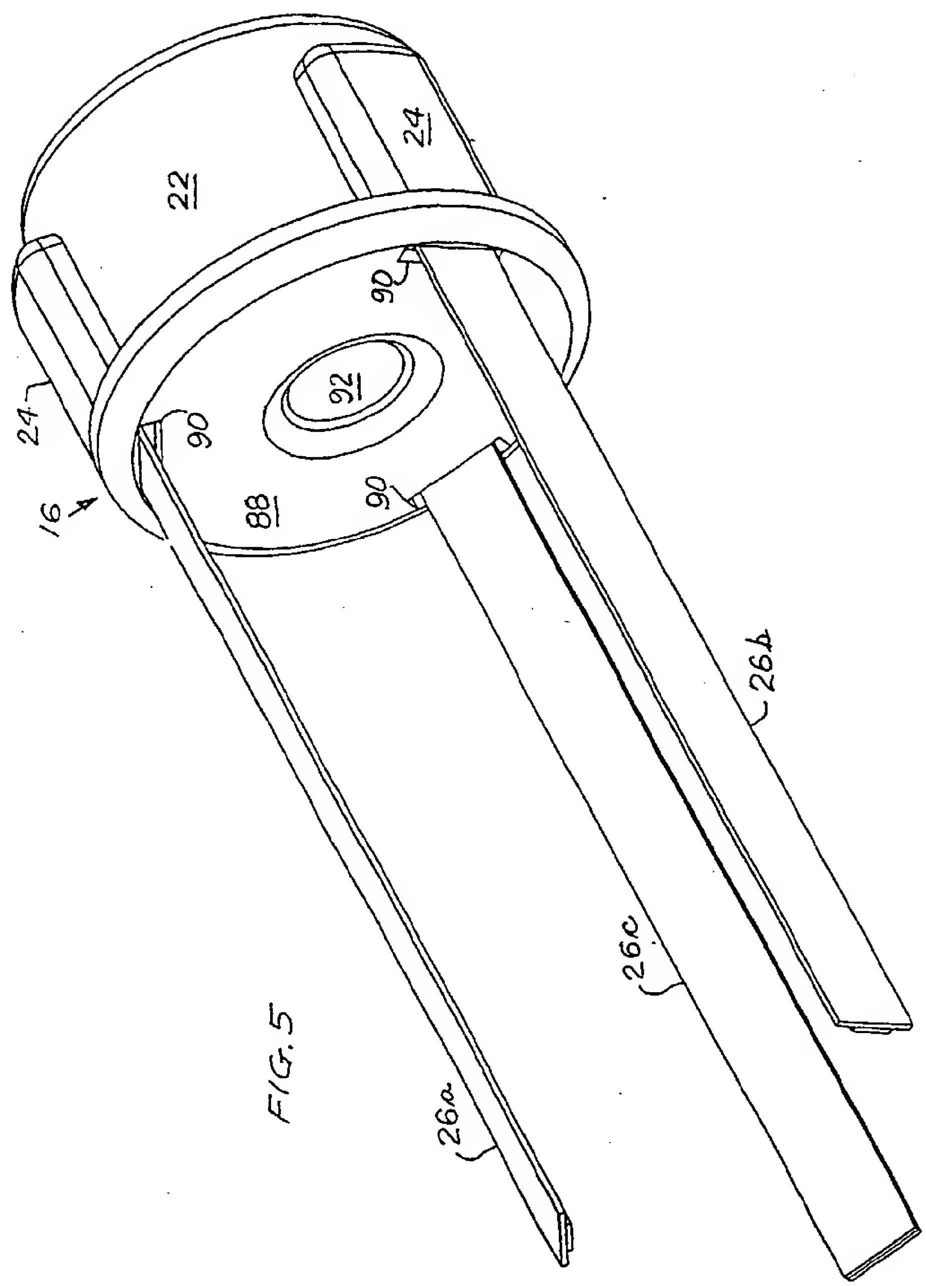
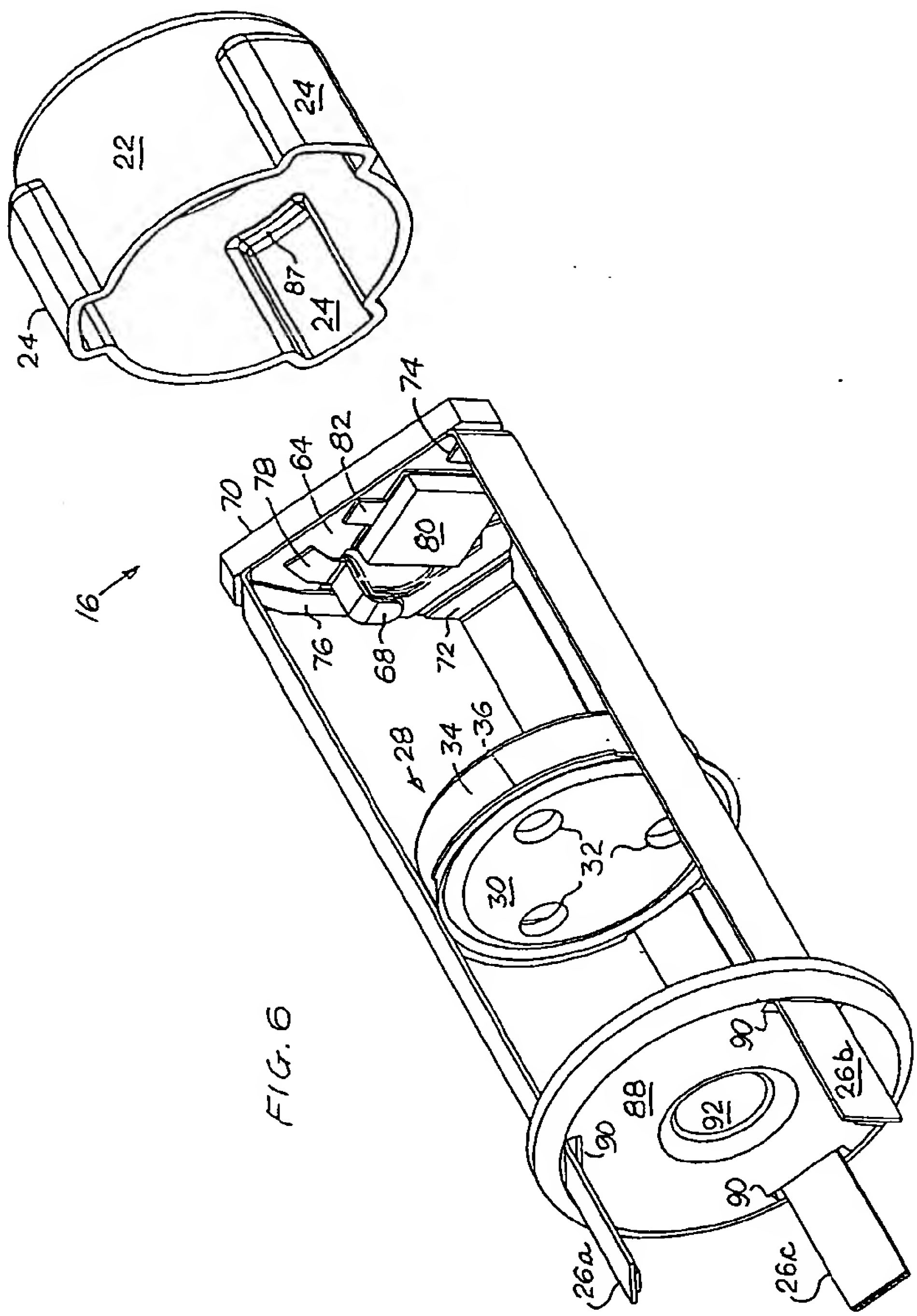


FIG.5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88
92
26b
90
90
26a
26c

FIG. 6

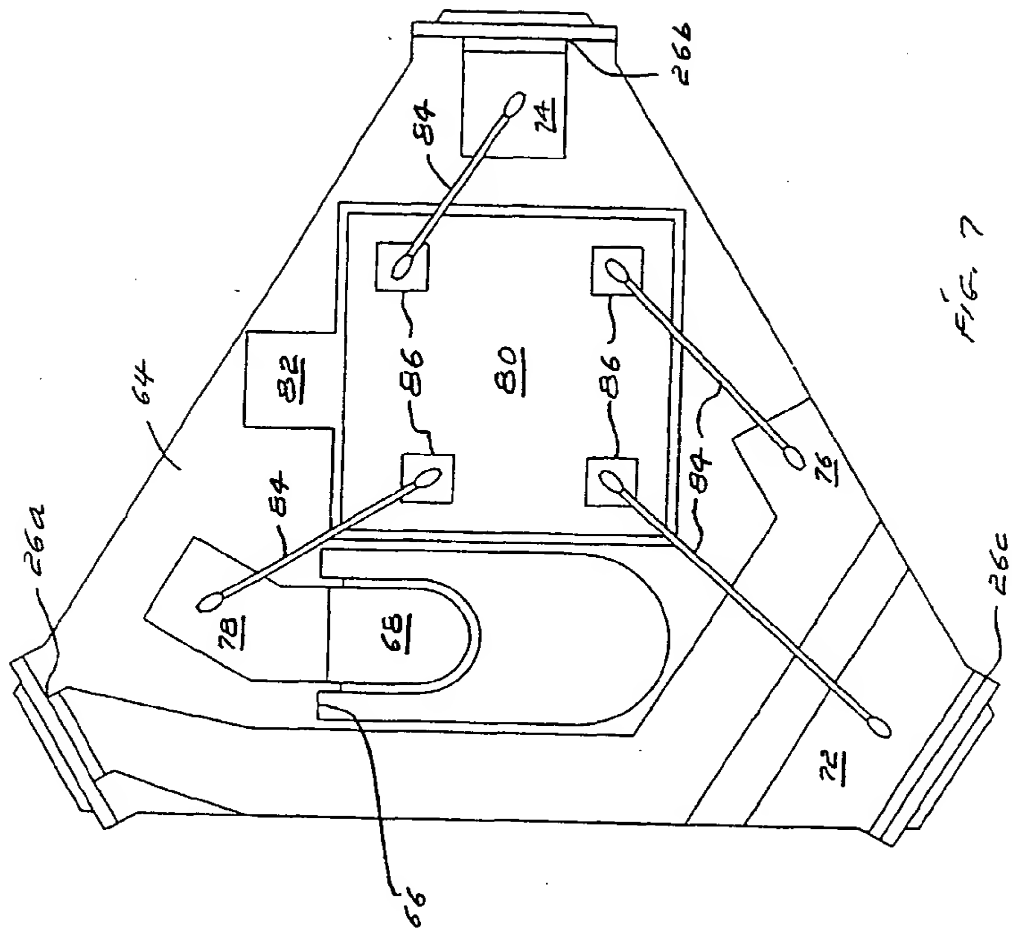


FIG. 7

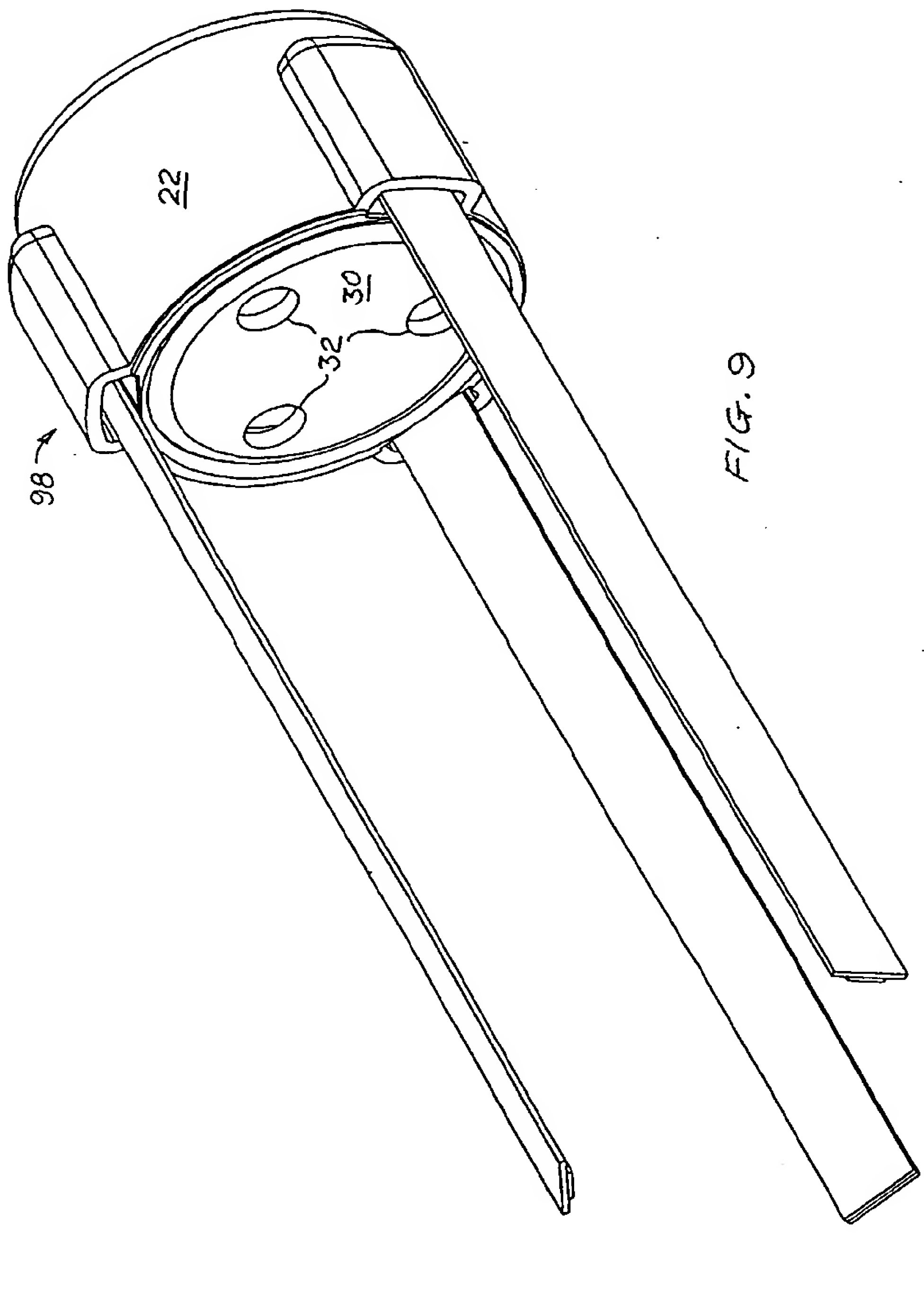


FIG. 9

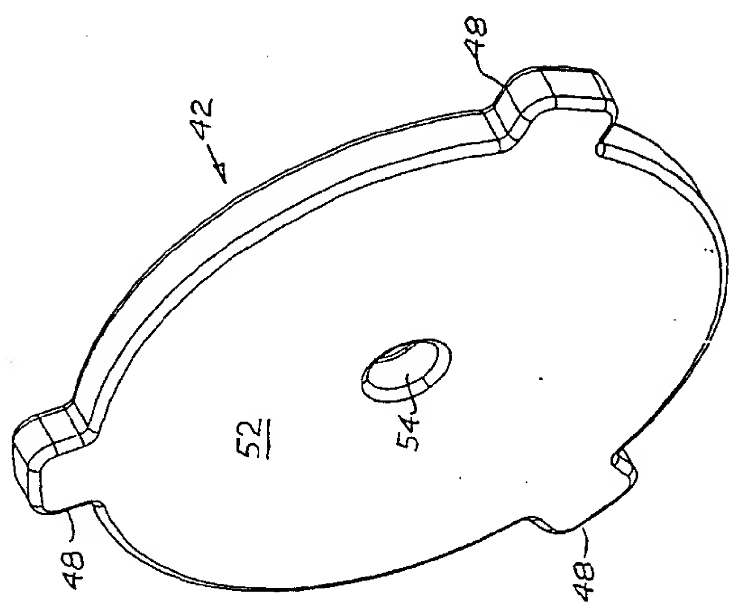


FIG. 8

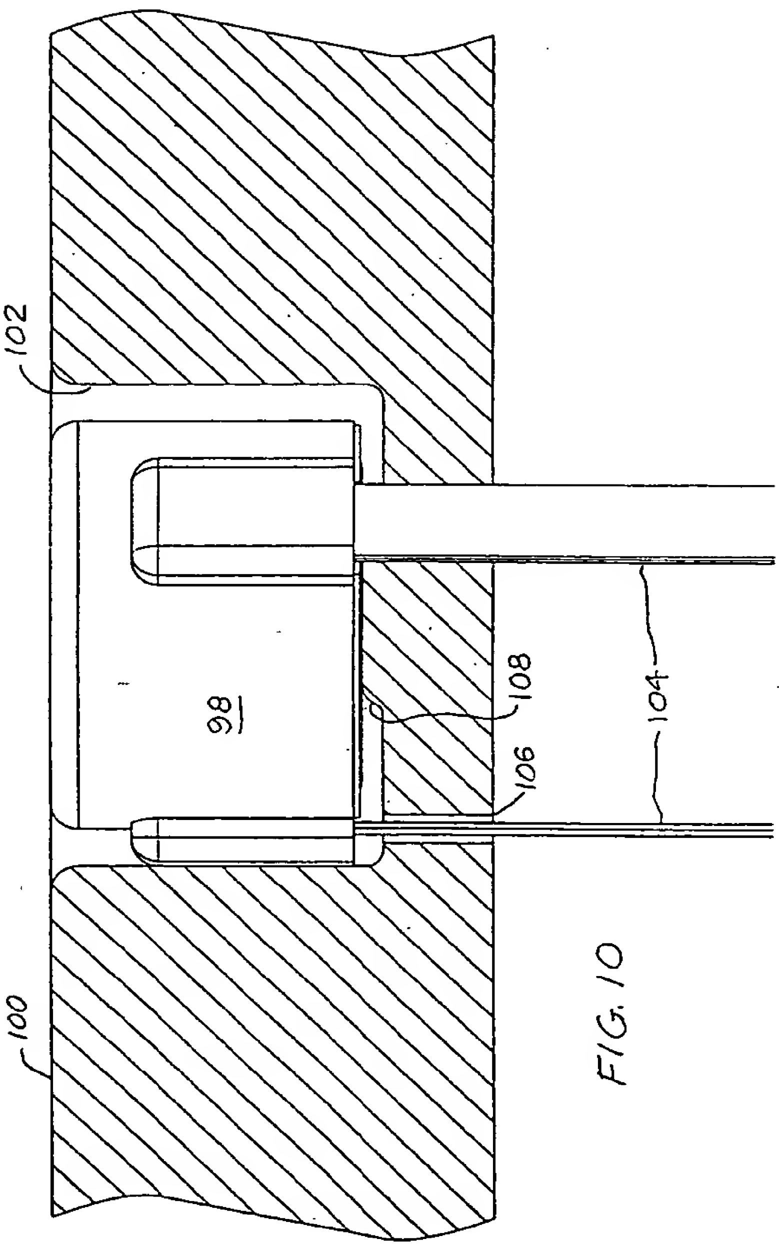


FIG. 10

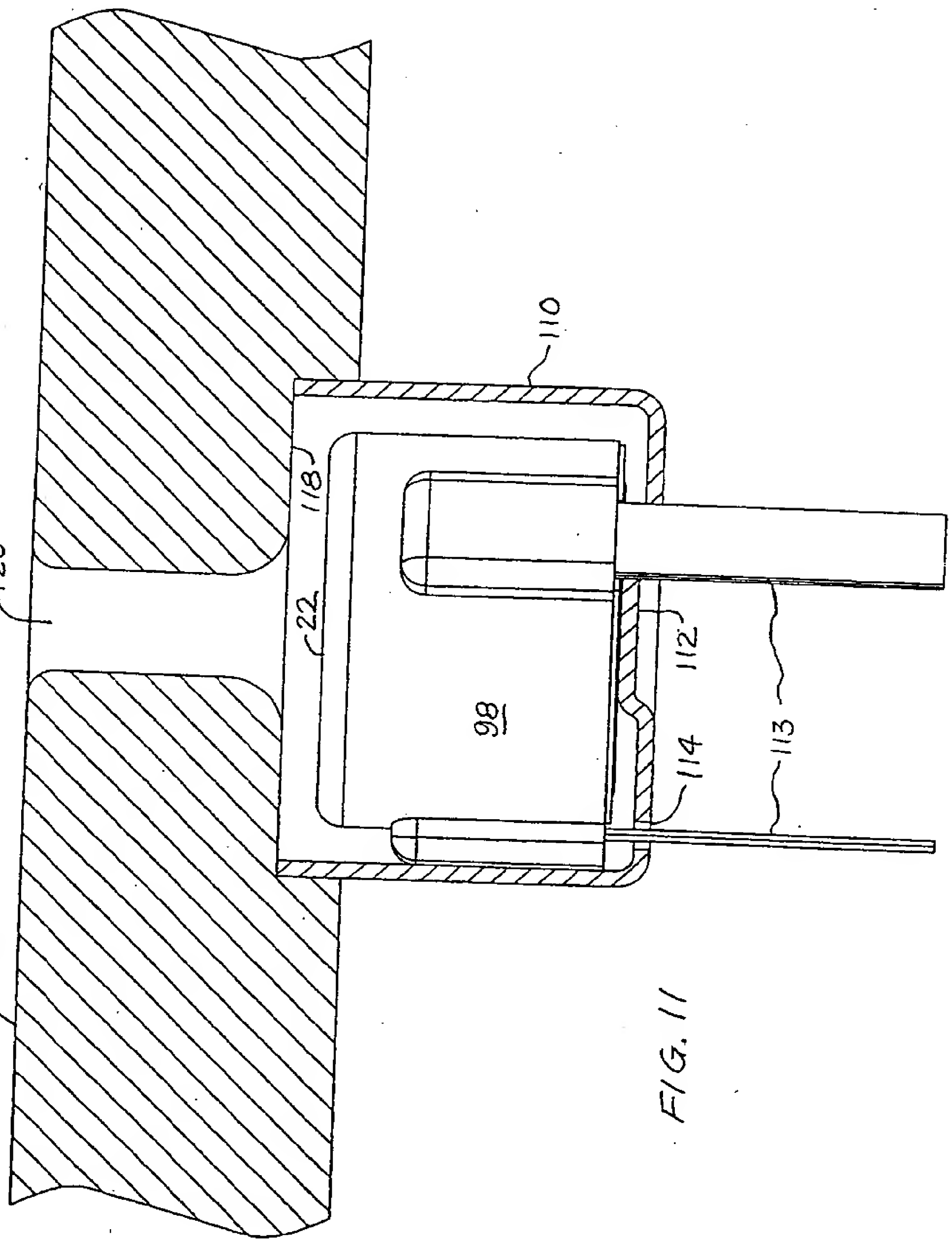


FIG. 11

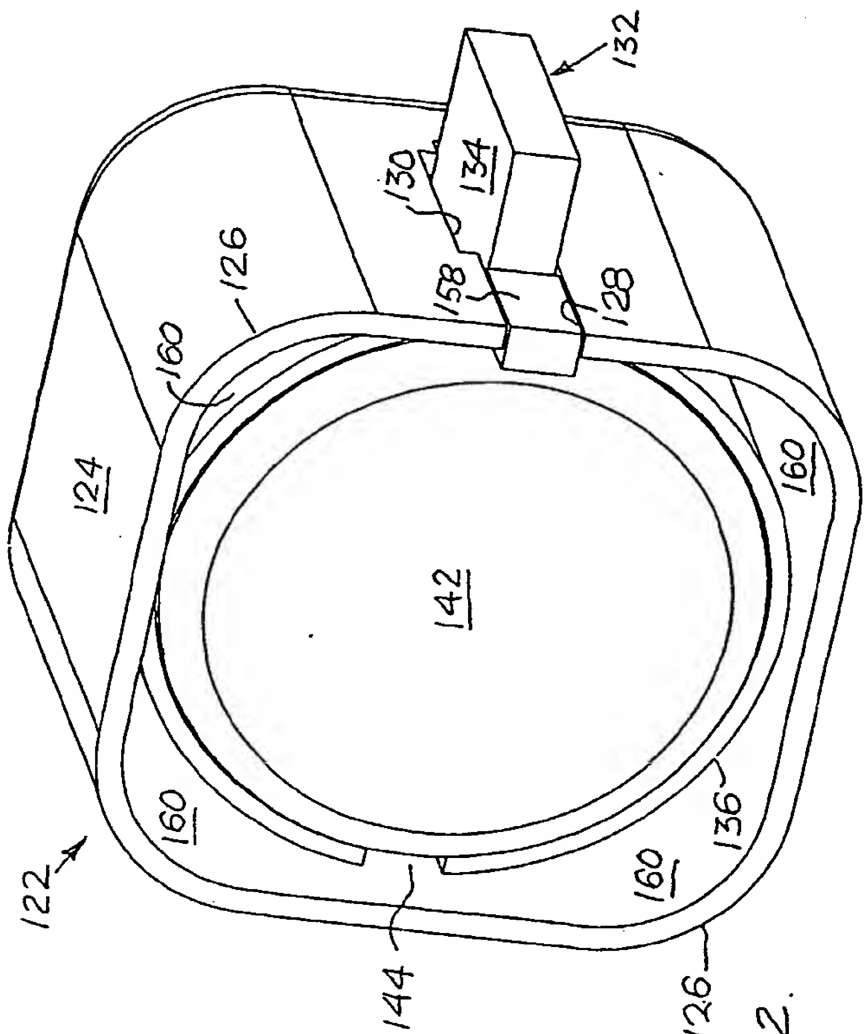
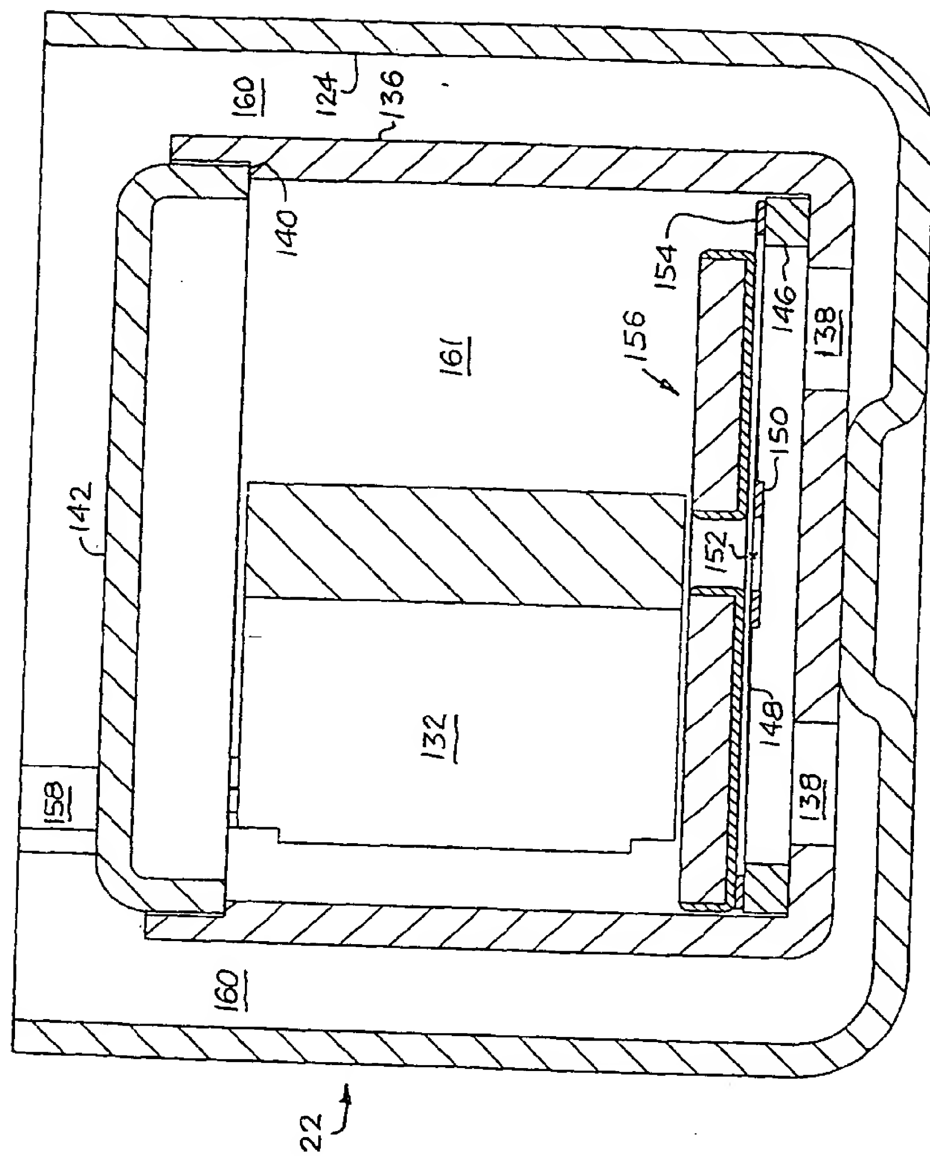


FIG. 12.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152
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132
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138
160
122

FIG. 13

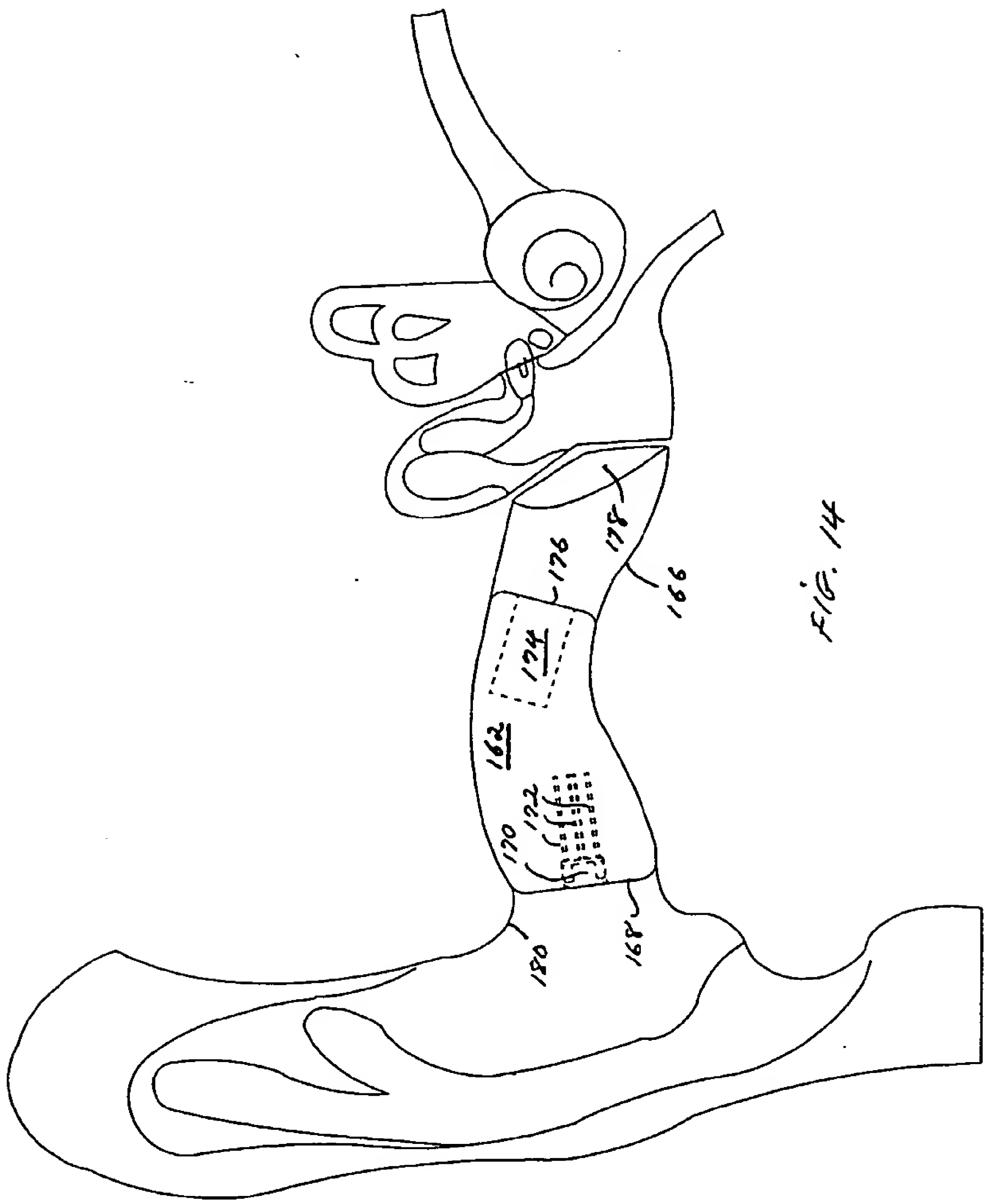

FIG. 14

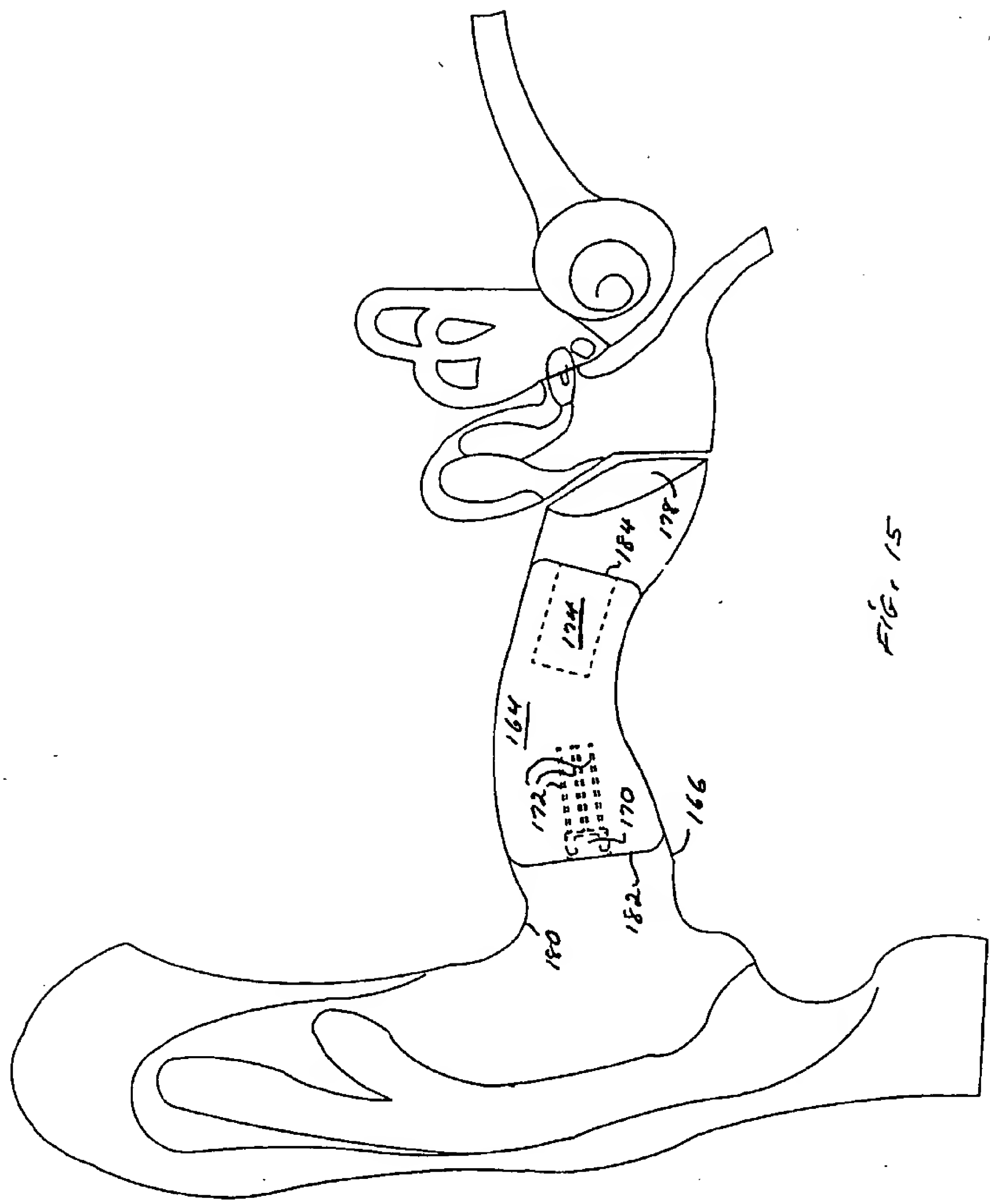

FIG. 15

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European Patent Office
Office européen des brevets

(11) EP 0 782 371 A3

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(54) Microphone systems of reduced in situ acceleration sensitivity

(57) An electroacoustic assembly comprising a microphone having a diaphragm and supported on a face plate susceptible to vibratory effects. Vibration sensitivity is reduced by opposing the pressure effects on the diaphragm caused, on the one hand, by vibration of the assembly in the ambient air mass and by vibration of the air mass leading from the ambient air mass to the diaphragm, and on the other hand, by vibration of the effective mass of the diaphragm, generally augmented with additional mass, and including the effect of the internal air mass adjacent the diaphragm. Applications include hearing aids in which the microphone and its support are mechanically coupled to receiver components that may impart significant motion thereto.

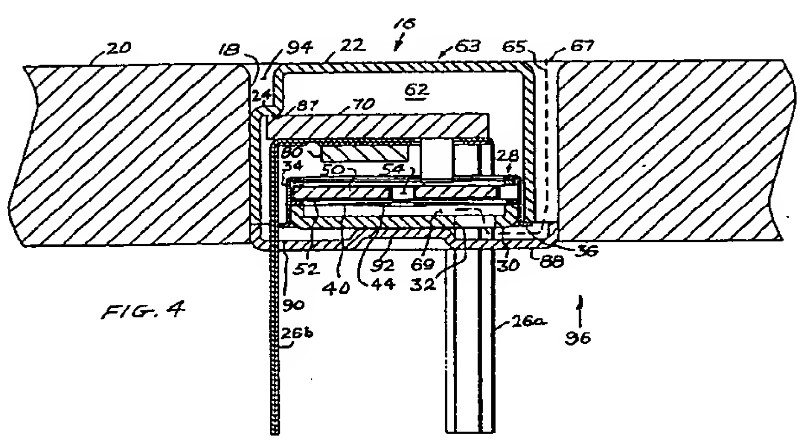

FIG. 4

EP 0 782 371 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 12 0478

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 466 676 A (VIENNATONE) 15 January 1992 * page 2, line 28 - page 3, line 3 * * page 3, line 20-31 * ---	1-9, 11-22	H04R25/02 H04R19/01
A	EP 0 556 792 A (KNOWLES ELECTRONICS) 25 August 1993 * column 1, line 58 - column 2, line 40 * * column 3, line 19 - column 5, line 19 * * column 7, line 11 - column 8, line 3 * ---	1-9, 11-21	
A	EP 0 533 284 A (MICROTEL) 24 March 1993 * column 1, line 1-11 * * column 3, line 31 - column 7, line 1 * ---	1-9, 11-22	
A	EP 0 107 843 A (KONOMI MASAO) 9 May 1984 * page 1, line 1-8 * * page 2, line 22 - page 3, line 24 * * page 6, line 13 - page 8, line 5 * * page 10, line 1 - page 11, line 19 * -----	1-13, 16-18	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 October 1998	Zanti, P

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